AD622676

Report OEM 1

Survey of

STUDIES and COMPUTER PROGRAMMING EFFORTS

for

- **RELIABILITY**

- **MAINTAINABILITY**
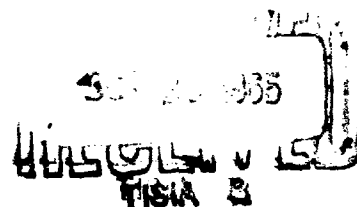
- **SYSTEM EFFECTIVENESS**

September 1965

Office of the Director of Defense Research and Engineering
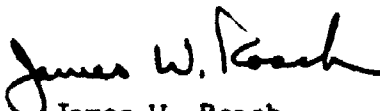
24 September 1965

FOREWORD

This report represents a preliminary, limited survey of efforts
under way or recently completed for computer programming or
techniques that are adaptable to computer operations in the
areas of system analysis for reliability, maintainability,
availability, system effectiveness, cost-effectiveness, system
simulation, circuit analysis, and failure mode and effects
analysis.

The rapid change in technology and quick obsolesence of the
material in this survey has lead to the printing of the report
despite the survey limitations. The information is being
provided for possible use by the Defense Department and
Industry project managers, designers, and any other personnel
such as support specialists in reliability, maintainability,
systems analysis, systems effectiveness, computer programming,
etc. The data referred to in the survey briefs are intended to
reflect available data, techniques, and studies reflecting
current technology. The industry contributors take no respon-
sibility in the use of such data, programs and techniques;
similarly, these data have no contractual status on the part
of the Department of Defense.

Recipients are solicited to offer information similar to that
contained in the survey briefs for similar studies, efforts
and available computer programs. Based on the number of new
project briefs submitted, consideration will be given to the
issuance of an expanded version of this report. Please send
your project briefs to the Office of the Director of Defense
Research and Engineering, Office of Assistant Director (Engineer-
ing Management), Pentagon, Washington, D. C. (20301).

It is preferred that the project briefs be limited to one
page and be prepared in the same format as those contained
herein. In forwarding your data, please include your company
or agency approval for release to print by the Government with
the purpose of making the data available to both industry and
government personnel.

James W. Roach
Assistant Director

SURVEY OF STUDIES AND COMPUTER
PROGRAMMING EFFORTS FOR RELIABILITY,
MAINTAINABILITY AND SYSTEM EFFECTIVENESS

Survey of efforts under way or recently completed for

computer programming or techniques that are adaptable

to computer operations in the areas of system analysis

for reliability, maintainability, availability, system

effectiveness, cost-effectiveness, system simulation,

circuit analysis, and failure mode and effects analysis.

The main sources of information for this survey
were Navy Applied Science Laboratory, Bureau of Ships,
Air Force Rome Air Development Center, ARINC Research
Corporation, Autonetics Division of North American
Aviation. Other activities queried were Office of
Naval Research, Army Research Office, and National
Bureau of Standards.

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SECTION I - SURVEY OF MATHEMATICAL AND SIMULATION MODELS

Title: Survey of Mathematical and Simulation Models
as Applied to Weapon System Evaluation

Abstract: A survey of 32 organizations (DoD Contractors)
resulting in 56 abstracts of models identifying
name of agency having done study, name of
sponsoring agency, description of model and
references to documentation.

Sponsor: Air Force Aeronautical Systems Division

Contract: AF 33(616)-7317

Contractor: University of Michigan

Status: Completed

Reports: ASD Technical Report 61-276 dated October 1961
(Defense Documentation Center No. 269-235)

SECTION II - RELIABILITY PREDICTION

Title: System Reliability Prediction by Function

Abstract: <u>Phase I</u>. A technique was developed for predicting the reliability of ground electronic systems prior to the actual design of the systems. Reliability data from 51 systems representing over two million system operating hours were analyzed to develop prediction equations based on generalized system parameters such as complexity, power consumption, and frequency. The prediction equations are of the form $\mathrm{Ln}\,\theta$ equals b_0 plus $b_1 X_1$ plus $b_2 X_2 \ldots$ plus $b_n X_n$, where θ is the predicted system mean life and the X_i are measures of equipment characteristics. The coefficients b_i were determined by multiple regression analysis. Approximately 40 possible characteristics were investigated. The technique also allows the estimation of confidence intervals for $\mathrm{Ln}\,\theta$. With the use of new data, the prediction technique can be updated at any time by the computation of new regression equations.

<u>Phase II</u>. As a follow-on effort the techniques developed for Phase I (ground electronic) will be expanded for use relative to Airborne Electronics and to predict both Reliability and Maintainability in the planning and initial design phases. The techniques will be based on correlations of MTBF and MTTR with the airborne functions of line replaceable units of the B-58 aircraft for which ARINC is presently collecting data. This data will be supplemented by ARINC's library on electronic functions of other aircraft, e.g., B-47, B-52, F-100, F-105 and some Navy aircraft. Phase II started 1 April 1964, and will be completed 4 September 1965.

<u>Note</u>. The importance and greatest value of this "function" prediction technique is in the early feasibility study and design stages.

Sponsor: Air Force, RADC

Contract: Phase I - AF 30(602)-- 2838
Phase II- AF 30(602)-- 3387

Contractor: ARINC Research Corporation

Status: Phase II active

Reports: Computer Program for Phase I predictions included in appendix of report

Computer: IBM-1401/Fortran II

Title: System Reliability Prediction by Function

Abstract: This study consisted of an effort to develop techniques
for predicting the reliability of electronic equipments and
systems during the early system planning stages. The
techniques were to be based on correlation factors which
would relate system, equipment or subequipment functions
by specific characteristics such as peak power to re-
liability levels achievable within the existing state of
the art.

The correlation studies performed were categorized into
three areas: radar, ground communication and data proc-
essing. A number of applicable radar and ground com-
munication systems were studied, and definite correlation
was found between functional characteristics and actual field
MTBF. The results of these correlation studies led to
the development of prediction techniques for both the
radar and ground communication categories.

Verification of these techniques was accomplished through
their application to other systems within the appropriate
category and comparison of the resultant predictions with
those calculated from actual field data. The satisfactory
results obtained led to the conclusion that the prediction
techniques were sound.

Sponsor: Air Force, RADC

Contracts: AF30(602)-2687
             AF30(602)-3288

Contractor: Federal Electric Corp.

Status: Report 2687 completed FY63
             Report 3288 completed FY65

Reports: RADC TDR 63-146
             RADC TDR 65-27

Computer: Can be programmed for any general purpose computer

Title: Reliability Prediction - Mechanical Stress/Strength
          Prediction

Abstract: This effort involves the study and investigation
           required to refine and reduce to practice the
           strength/stress interference theory technique for
           designing to and predicting the quantitative
           reliability of mechanical parts under fatigue
           or constant loading. The statistical nature of
           both the strength and stress indicate that the
           results of this study will be amenable to computer
           manipulation.

Sponsor: Air Force (RADC)

Contract: Awarded March 1965

Contractor: University of Michigan

Status: Under way

Report:

Computer:

Title: Reliability Prediction (Mechanical Systems)

Abstract: Evaluation of alternate designs and prediction
of inherent reliability utilizing basic failure
mechanisms, of parts and materials, related to
Service application environments.

Sponsor: Navy BuShips

Contract: NObs-88628

Contractor: American Power Jet Company

Status: Under way

Reports:

Title: Updating of MIL-HDBK-217A "Reliability Stress and Failure Rate Data for Electronic Equipment"

Abstract: An effort to update part failure-rate data and application data used in prediction of Reliability using a part failure rate computation. This does not include parameter drift considerations; it is limited to basic catastrophic failure modes and mechanisms. The prediction computation is not necessarily done by computer but can be for complex systems or circuit configurations.

Sponsor: Navy, BuWeapons (NAD Crane)

Contract: NAD Crane Contract

Contractor: Radio Corporation of America

Status: Completed - May 1965

Reports: Final Product is in process of tri-Service co-ordination

Computer: Not applicable. Data may be put into any general purpose computer.

Title: CRAM (Computerized Reliability Assessment Method)

Abstract: CRAM is a computer method which is used to predict system reliability. It permits the user to proceed in an orderly manner from a complex block diagram of a system whose components may fail in many modes to a final reliability prediction for the system.

Computations which can be almost impossible to carry out manually, become strictly a routine procedure of entering the proper data as program inputs.

To use CRAM, the engineer, having defined the level of detail of the analysis, draws a reliability diagram in an appropriate manner. The diagram is routinely converted into a computer program input. Component failure rates and any modifying factors are also used as inputs to arrive at the desired results.

<u>Note</u>: Principal areas of improvement in the existing program lie in increasing the size and complexity of the systems which can be evaluated, and improving the efficiency of certain sub-routines to reduce computer running time.

Sponsor: NASA, Marshall Space Flight Center

Contract: NAS-8-11067

Contractor: ARINC Research Corporation

Status: Under way

Reports: ARINC Monograph No. 11 by D. E. van Tijn and ARINC Report 294-02-14-444

Computer: IBM 1401, 16K Memory/AUTOCODER

Title: Beam Pattern Degradation (Sonar Arrays)

Abstract: Simulation program for the analysis of sonar
             transducer arrays to determine performance
             degradation as a function of inoperative
             transducer elements. The program defines system
             mode failures within the framework of the
             allowable system performance degradation for
             the applicable mode. A program has been
             developed for cylindrical arrays and a new
             contract effort is planned to develop a computer
             program for application to conformal and planar
             arrays (extension of AN/SQS-26 model).

Sponsor: Navy, BuShips

Contract: Nobsr-91039

Contractor: Tracor Inc.

Status: The program has been completed for the AN/SQS-23 and
          AN/SQS-26 Sonars and will be used in the reliability
          prediction techniques applied to AN/SQS-26 production
          contracts. Efforts are under way to initiate similar
          studies in connection with Conformal/Planar Arrays
          Development Programs.

Reports: Series of Tech. Reports prepared by Tracor Inc.
           relative to AN/SQS-26

Computer: CDC 3200/CDC-160A(Fortran)

Title: Reliability Simulation Model (APOLLO Mission)

Abstract: A Reliability Simulation Model that simulates the operation of a vehicle for a large number of missions, and determines the number of mission successes and mission failures by the application of a Monte Carlo technique.

In applying the simulation model, logic diagrams are constructed to define the combination of components required to complete each function of each phase of a mission. The failure density distribution for each of these components is obtained from test data or estimated failure rates, and the component time of failure is determined by the application of the Monte Carlo technique.

When mission failures occur, the model becomes a decision-making device, as it determines what form of an alternate mission is to be initiated. The form of alternate mission is a function of the combination of component failures at the time of mission failure. The alternate mission may be a continuation of the mission with lesser mission objectives or a return mission to enhance the safety of the crew. Thus, the model provides the probability of both mission success and crew safety.

The Reliability Simulation Model, while applicable to any form of equipment and/or mission configuration, was designed primarily for the reliability analysis of the APOLLO Lunar Landing Mission.

Sponsor: NASA

Contract: APOLLO Project

Contractor: North American Aviation (Space and Information System Div.)

Status: Active

Reports: Proceedings 10th National Symposium Reliability and Quality Control

Computer: IBM-7094

Title: SOAR-II

Abstract: Special purpose program tailored to the
APOLLO mission simulates failures using
Monte Carlo technique to evaluate and
predict probability of "Mission Success"
and "Abort Success." Inputs are both
random and fixed and outputs are averages
of success probabilities for every 500
trials.

Sponsor: NASA, Office Manned Space Flight

Contract: APOLLO Project

Contractor: General Electric - Tempo

Status: Active

Reports: NASA, OMSF Tech Memo
M-TJ-6300.001 (RA-10)

Computer: Not known

Title: Mechanized Aircraft Reliability Analysis
Model

Abstract: Method for reliability evaluation of alternate
system configurations for selection of an
optimum system design and measurement of
reliability growth. Computer program for
rapid calculation enabling timely decisions
and configuration control.

The emphasis is toward a consistent and
realistic reliability evaluation that measures
the achieved reliability and monitors the
reliability growth throughout the development
and operational life of airborne systems.

Sponsor: Lockheed - Georgia

Contract:

Contractor:

Status:

Reports: Proceedings 10th National Symposium on
Reliability and Quality Control (Page 560)

Computer:

Title: Prediction of Circuit Drift Malfunctions of Satellite Systems

Abstract: The purpose of this study was to evaluate existing statistical
analysis methods for determining the probability of malfunction
of transistor circuits due to degradation of component part
parameters during operating life. Circuit output parameters
are expressed as functions of several part parameters charac-
terized by probability density functions, which may be determined
from test operation of part samples for the required time.

Analytical results are evaluated by comparison with results
obtained from test operation of circuit samples for the
required time. Comparison of both the number of drift mal-
functions and the distribution of circuit parameters are made.
Test sampling error and measurement errors are considered. The
results lead to the following conclusions:

- Accurate estimates of the distribution of circuit
  output parameters - voltage levels and transient
  response times can be obtained during test operating
  life.

- The probability of drift malfunction of circuit out-
  put parameters during test operating life can be
  estimated accurately.

- Experience with the reduction of component part test
  data to derive probability density functions for part
  parameters suggests that further improvement in
  accuracy and refinement of analytical methods can be achieved
  through part tests which are designed specifically to
  yield statistical analysis data.

- Each of the three analysis methods investigated -
  combination of distributions, regression, and Monte
  Carlo - has advantages which merit consideration in
  any particular application; however, for general use,
  the Monte Carlo has fewer limitations.

Sponsor: Air Force, RADC

Contract: AF 30(602)-2418,

Contractor: IBM, Owego, New York

Status: Completed 1963

Reports: RADC TDR62-227

Computer:

Title: Mathematical Simulation for Reliability Prediction

Abstract: Phase I. A study program for the development of
techniques for predicting the reliability of electronic
systems from statistical information about the per-
formance of system components. The problem of
determining initial system performance and system
performance over a time period, given changes in
component characteristics in time, is analyzed.
The prediction of the reliability of systems whose
performance is measured on a continuous scale and
which are subjected to degradation type failures
is emphasized. Catastrophic failure models including
repair and redundant elements are also discussed.

Phase II. The second phase of the study relates
to the transfer functions which have been developed
in this phase which are mathematical models of the
actual systems to be evaluated. They are used to
determine system performance when component charac-
teristics vary from nominal values as a result of
(1) manufacturing and handling, (2) degradation due
to age, (3) internal and external random stresses.
Form of output is magnetic tape and plot.

The circuits analyzed in this report will not only
serve as vehicles to substantiate the findings of
the Phase I, but will in addition serve as a nucleus
for a library of preferred designs with defined life-
time characteristics.

Sponsor: Air Force, RADC

Contract: AF 30(602)-2376,

Contractor: Sylvania Electronic Systems Division

Status: 1960-63 effort, completed

Reports: Phase I, RADC-TR-61-299 "Math Simulation for Reliability
Prediction".
Phase II, RADC-TR-63-87 "Transfer Functions in Math
Simulation for Reliability Prediction"

Computer: Sylvania Model 9400

SECTION III - MAINTAINABILITY PREDICTION

Title: M Prediction by Function

Abstract: This is a current effort scheduled for completion
in September 1965, and being conducted in conjunction
with a "System Reliability Prediction by Function"
study. It will provide a technique for establishing
a quantitative relationship between equipment (LRU)
Line Replaceable Unit function, i.e., transmitter,
receiver, scope, recorder, data processor, display,
etc., in terms of M design characteristics expressed
as an influence on MTTR. Such M features as skill
level, packaging, accessibility, adjustments, depth
of-penetration, etc., will be included. The findings
will be organized in a manner convenient for use
(math model/equation_ in predicting equipment (LRU)
M during planning stages when required function and
some performance parameters (weight, volume) only
are known and during early design before circuit
detail has been decided.

Sponsor: Air Force, RADC

Contract: AF 30(602)-3387

Contractor: ARINC Research Corporation

Status: Under way

Reports:

Computer: IBM 1401/Fortran

Title: OPTIC

Abstract: A mechanization of elemental maintainability
            design information to translate maintenance
            source data into maintenance procedural
            instructions. Iterative process of analyzing
            maintainability design and the output is a
            set of procedural maintenance instructions
            optimized from a time and cost standpoint.

Sponsor: Republic Aviation Corporation

Contract:

Contractor:

Status: Active

Reports:

Computer: General Purpose Digital Computer

Title: Criteria for Discard-at-Failure Maintenance

Abstract: A mathematical model was developed serving as a
            design decision tool describing the relationships
            between module size, maintainability, and total
            resource cost. The model is adaptable for use
            during early design phases of a development program
            by minimizing the number of variables and maximizing
            use of cost factors which are constant. It is
            flexible to allow for variations in maintenance
            planning and up-dating of values furnished for the
            factor constants. The model is capable of defining
            which of the two alternates, repair-at-failure
            maintenance or discard-at-failure-maintenance is
            most economical, and capable of determining the
            optimum discard-at-failure module part density.
            Resource costs considered included manpower, materials,
            facilities, test equipment expenditures at the
            various maintenance echelons. The model is a
            difference equation which can be manually applied.

Sponsor: Air Force, RADC

Contract: AF 30(602)-2681,

Contractor: IBM, Owego, New York

Status: 1962-63 effort completed

Reports: AD-405779 (RALC TDR-63-140)

Title: Validation of Criteria for Discard-at-Failure Maintenance

Abstract: The mathematical model developed under previous contract AF-30(602)2681 (see Page III-3) was revised to more exhaustively reflect all pertinent cost and design factors. The finalized mathematical model was validated empirically by comparing actual resource costs for an existing operational equipment design in repairable RAFM (Repair at Failure Maintenance) form with projected resource costs for an identical equipment redesign on paper in accordance with DAFM (Discard at Failure Maintenance) criteria. The results of this work provide definite criteria for judging the relative cost merit of RAFM vs DAFM in a given equipment or system situation.

Sponsor: Air Force, RADC

Contract: AF(30)(602)-336

Contractor: Radio Corporation of America, Camden, New Jersey

Status: Completed July 1965

Reports: RADC-TR-65-214

Computer: In a form to be programmed for any general purpose computer.

Title: Refinement of M Prediction Technique

Abstract: The study has provided a technique for quantifying
the relationship between circuit design features
and M. Use of empirically derived repair times in
conjunction with a circuit design feature diagram
provides guidance early in equipment design for
selection of circuit configurations which could
satisfy a repairability requirement. The tech-
nique will also facilitate the evaluation of
existing off-the-shelf circuitry to predict the
associated repair time and determine the extent
of redesign necessary to provide the greatest M
improvement. The M design criteria is applicable
to all repairable conventional and semi-conductor
circuitry found in aerospace and ground electronics.
The criteria are graphically presented for ease of
application and expressed quantitatively, relating
circuit design to malfunction diagnosis, repair,
and checkout. It is significant to note that al-
though only 16 basic circuit types were studied, the
technique permits the evaluation of MTTR for any
circuit employing any combination of the nine
basic design features.

Sponsor: Air Force, RADC

Contract: AF 30(602)-3033

Contractor: Vitro Labs, Silver Spring, Maryland

Status: 1963-1964 effort; completed

Reports: AD-610073
RADC-TDR-64-308 "Circuit MTTR as a Function of Design"

Computer:

Title: Maintainability Prediction Program

Abstract: This program implements the prediction technique developed by ARINC Research Corporation. Inputs to the program, in the form of equipment characteristics, are converted by the computer to distributions of active repair times and system down times.

The inputs are typified by such characteristics as numbers of components, flight line replaceable components, spares, test points, and readouts; and failure rates, mission length and maintenance policies. A major advantage of the output is the fact that it is in the form of a distribution rather than a point estimate.

Improvements in the program must be predicated on refinement of the basic prediction technique.

Sponsor: Air Force, WPAFB (AFSC - Dir. Strategic and Tactical)

Contract: AF 33(657)-10594

Contractor: ARINC Research Corporation

Status: Completed

Reports: ARINC Report 267-02-6-420

Computer: IBM 1401 and 7090
Programs available at ARINC for 1401 and at WPAFB for 7090

Title: M Techniques Study

Abstract: Furnishes quantitative measurement of ground
            electronic system/equipment M through use of
            a prediction technique which provides an
            estimate of equipment downtime through measures
            of M design. Complementary to the prediction
            technique, design analysis methods were formulated
            to permit M design selection decisions to be
            made during equipment development.

Sponsor: Air Force, RADC

Contract: AF 30(602)-2057

Contractor: RCA Service Company, Camden, New Jersey

Status: 1960-63 effort; completed

Reports: RADC TDR-63-85 "Maintainability Technique Study", Vol. I
           AD-404899
           AD-404898 "Maintainability Engineering", Vol. II

Computer:

SECTION IV - SYSTEMS EFFECTIVENESS

Title: Availability Evaluation Program (NARSE-I)

Abstract: This program permits the efficient repetitive evaluation of the reliability, maintainability or availability of a system as variations are made in failure or repair characteristics, or in system configuration.

Once a reliability block diagram has been established for a system, the program can calculate for any specified time the reliability and/or availability of the system. The failure and repair times for the individual blocks can have exponential normal or log-normal distributions or can be entered as probabilities. The program can handle partial, time dependent, and standby redundancy.

<u>Note</u>: As presently written, this program is limited to evaluation of reliability, maintainability, and availability. Additional effort should be directed toward the inclusion of capability characteristics so that total system effectiveness can also be treated.

Sponsor: Navy, Applied Science Lab, New York

Contract: N-140-(62462) 76790B

Contractor: ARINC Research Corporation

Status: Current. Program available from NASL.

Reports: Report No. 321-01-1-468 of 31 January 1965 (Confidential)

Computer: IBM 1401-16K

Title: System Effectiveness and Design Adequacy

Abstract: Analytical model related to System Effectiveness and Design Adequacy simulation and evaluation. Applicable to aircraft systems with eight or less subsystems and eight or less system functions and assuming no inflight repair; also, unit performances are independent. Printed output states effectiveness as a probability.

Sponsor: Air Force; Aeronautical Systems Division

Contract: AF 33(657)-10594

Contractor: ARINC Research Corporation

Status: Complete for single systems; to be extended

Reports: ARINC Publication 267-01-7-419

Computer: IBM 1401/Fortran II

Title: System Effectiveness Evaluation

Abstract: During the course of ARINC Research Corporation's efforts
for WSEIAC, a computer program was developed for employing
the System Effectiveness evaluation procedure recommended
by Task Group II of WSEIAC.

The basic program provides for analytic combination of the
three elements of Effectiveness; i.e., availability,
dependability, and capability. (These elements must be
represented by vectors or matrices in order to consider
the multiple system states which are possible).

For specific systems, variations in the basic program are
made. Programs were written and employed for Evaluating
the specific systems discussed in the following:

    (1)   Section V, Volume II, Task Group II Report
    (2)   Example A, Volume III, Task Group II Report
    (3)   Example C, Volume III, Task Group II Report

While some variations did exist, in general, the computer
accepted as inputs the reliability, maintainability, and
capability indices of the equipments comprising the
systems; from these, it computes the elements of the several
vectors and matrices; and finally, it multiplied the vectors
and matrices to obtain Effectiveness. Automatic parameter
variation (i.e., several values of mean-times-between
failure for each equipment) can be included and the re-
sulting Effectiveness values computed.

Areas in which improvements are required will best be un-
covered when the program is applied to actual, as opposed
to the hypothetical, systems evaluated to date.

Sponsor: ARINC Research Corporation in-house effort in connection
with Air Force Weapon System Effectiveness Industry
Advisory Committee (WSEIAC) Study.

Status: Program available from ARINC

Report: WSEIAC Report Task Group II, Vol. II

Computer: IBM 1401-1bk

Title: SEA (System Effectiveness Analyzer)

Abstract: The program is intended to have capabilities for
evaluation (prediction) and optimization of systems
in terms of their systems effectiveness or cost
effectiveness attributes. Optimization can be
performed either as a selection problem among a
postulated set of alternatives or as an allocation
problem.

The program contains several features that make it
suitable for the solution of a wide variety of problems
while requiring only a simple set of rules for the
direction and execution of tasks. This is accomplished
by means of a routine whereby various organizational
(structural) and functional relationships that govern
system operation and behavior, at various levels of
interest, are stored on tape and called for as needed.
In addition, a command and definition language has
been developed which enable the user to communicate
his problem in simple terms. Provision is also made
for revision and updating of the various libraries and
for storage and recall of analyzed configurations.
Capability also exists for modifications and altering
systems during analysis as well as assessment of
sensitivity of various parameters to selected effective-
ness measures.

Sponsor: Naval Applied Science Laboratory, New York

Contract: N140(62462)-77459B

Contractor: Computer Applications Inc.

Status: Active, users language, system of function libraries developed

Report: User Language Available, also Program Reports 30 November
1964 and 31 January 1965

Computer: CDC 6600 (Control Data Corp.)

Title: (SEE/AN) System Effectiveness Evaluation Analyzer

Abstract: A Steady-State Effectiveness Model. SEE/AN involves a steady-state system effectiveness model that computes equilibrium distributions of effectiveness characteristics. It is most useful for large systems composed of 10 to several hundred subsystems in which sustained operations, including real-time maintenance, is required.

This model, when implemented with the aid of a computer program, will show the effects of malfunction, scheduled and unscheduled maintenance, logic and time of detection, localization, fall-back, and recovery upon the performance distributions that form the program outputs. System degradation requires particular attention during transitions in system operating modes. The SEE/AN-I program, which is used to perform the final computations, requires inputs that include the following:

(1) Definitions of groups of functionally interchangeable subsystems that exist in the system.

(2) The mean-up-time (MUT) and mean-down-time (MDT) for the subsystems of each group, measured or calculated from formulae in the associated program documents.

(3) The number of subsystems that are in each group.

(4) Definitions of states, and groups of states of interest. All states that are unspecified are automatically placed together with the null state (all subsystems Down).

(5) Values of state performance parameters. As many as 10 performance parameters may be specified. These may be of either the additive type (more are better, e.g., capacity) or the time-descriptive type (fewer are better, e.g., service time). These parameters differ in the automatic corrections that are made for system recovery time, and for non-performance in the null state.

(6) Values of thresholds. Thresholds allow the distributions of the performance parameters to be compared with specified performance values.

Program outputs include: (1) the probability of each state specified on input, (2) the mean-time spent in each of the states specified on input, (3) probability distributions for each performance parameter specified on input, and (4) comparison of the performance parameter distributions with the specified threshold values.

Also see (SEE(SIM)) Simulation Program (P. IV-6).

Sponsor: DCA

Contract: DCA Contract SD-194

Contractor: Auerbach Corporation

Status: Currently being used in the Autodin Project for Proposal Evaluation, Design Prediction and System Progress during production.

Reports: (a) Spec MIL-A-55246 (EL-Autodin)
(b) IEEE Paper "System Effectiveness" Philadelphia Section,10Feb65

Computer: Philco S-2000, IBM-7090, Fortran II

Title: SEE(SIM) System Effectiveness Simulation

Abstract: SEE(SIM) was developed in support of SEAHAWK and
PACED. It is capable of simulating the effective-
ness characteristics of a wide class of systems.
The Simulator generates failures and repairs of
subsystems (units) in Monte Carlo fashion in
accordance with prescribed probability distri-
butions. The program also allows for consideration
of task priorities and inclusion of recognition
times (mean and variance of times necessary to
recognize a failure) and adjustment times (speci-
fication of alternate modes of operation of the
system upon recognition of a failure and mean
times required to accomplish adjustments). The
program outputs include the following:

(1) Tables that show the number of times the
system was not performing at a specified
level for a specified length of time.

(2) The mean duration of an occurance, and
deviations from the tabulated mean.

(3) Probability of achieving given levels
of performance.

Also see (SEE(AN) Analyzer Program P. IV-5)

Sponsor: Navy, BuShips

Contract: Nobsr-91244

Contractor: Auerbach Corporation

Status: Current-being used

Reports:

Computer: IBM-7090/7094(GPSS II Language)

Title: ASW Mission Effectiveness

Abstract: Program to (a) evaluate the contribution of each
sub-system to over-all mission requirements,
(b) establish contribution of each sub-system to
over-all mission effectiveness, and (c) provide
means for optimization of tactics.

Does not consider factors such as false alarms,
sonar interference, countermeasures, cost, manning,
etc.

Work done is support of DE-1052 Advanced ASW Ship.

Sponsor: Navy, BuWeapons, Navy Weapons Laboratory

Contract: N178-85-44

Contractor: ARMA

Status: First phase completed. Currently being programmed
and updated. Computer program will be available
for exercise 1 July 1965.

Reports: Phase I - 9 partial reports each covering sub-model

Computer: Stretch (IBM-7030)/Stretch Language (Fortran 4)

Title: Evaluation of the System Effectiveness of the
        E2A/ATDS

Abstract: A program has been developed to assess the effective-
           ness over relatively long periods of time of a system
           capable of operating in several different modes. The
           system capability is a function of the system state
           at a particular time; the system state, in turn, is
           a function of the condition of the equipments comprising
           the system. The measure of effectiveness is the integrated
           capability of the system over the total mission time.

           In the system under study, a simulation approach was
           employed because of the difficulties involved in
           analytically describing the multiple state transitions
           which could occur.

           The simulation considers such variables as the number
           of systems available for patrol duty, reliability of
           the components of the system, maintenance policy, times
           required to restore failed units, and various operational
           parameters such as refuel times, launching and landing
           times, and the number of aircraft allowed in the air
           simultaneously. The program allows variation of these
           parameters and shows the relationship between system
           effectiveness and the various parameters.

           Improvements in the program to permit inclusion of such
           factors as logistic considerations, shop maintenance,
           and maintenance efficiency as fleet experience is obtained
           should be incorporated.

Sponsor: Navy, BureauWeapons

Contract: NPOLA-N-123(61756)-50249A

Contractor: ARINC Research Corporation

Status: Completed February 1965

Reports: ARINC-322-01-2-470

Computer: IBM-7090

Title: Techniques for Prediction of System Effectiveness

Abstract: The purpose of this effort was to investigate and develop
a mathematical model capable of predicting the effectiveness
for any given operational environment. The model was expected
to be able to account for the influence of all important
parameters of hardware and environment, such as reliability,
redundancy, man-made and natural environments, etc., and to
express the effectiveness of the system in terms of a single
figure of merit.

The SPAN (System Performance Analysis) Model developed in the
course of the study utilizes both physical and mathematical
modeling techniques and is derived from probability and
information theory and the energy flow equations of Laplace
and Helmholtz. By transforming system and environmental
parameters into SPAN language and appropriate effectiveness
numbers, the system is simulated by electrical networks. As
an example, transmission phenomena are represented as "T"
networks in which the values of the series arms represent
the lossy transmissions of both energy and information, and
the values of the shunt arms represent the transfer ratios.
The initial values of resistance are determined by the
product of the effectiveness numbers and a constant resistance
determined by the simulation equipment used. The total
system effectiveness in this type simulation is represented
as an output power which can be optimized by varying the
resistances of the simulator. The new resistance values, when
translated back into real system parameters, then represent the
most effective system configuration.

Contained in this report are a series of transforms for the
conversion of parameters to SPAN language and effectiveness
numbers, and a demonstration of the simulation technique for the
case of a hypothetical system.

Sponsor: Air Force, RADC

Contract: AF 30(602) 273

Contractor: Nortronics

Status: Completed

Reports: RADC TDR 62-540

Computer:

Title: Techniques for Prediction of System Effectiveness

Abstract: The broad problem of the prediction of system effectiveness is investigated with the objective of determining the kind of mathematics, mathematical models or mathematical procedures capable of supporting a significant amount of the required applications. Special attention is given to those problem areas in which the computation of effectiveness indices can not exclude consideration of reliability and maintainability. For such problems it is concluded that feasible solutions, capable of the timely and economical generation of needed results, exist only in terms of hybrid Monte Carlo and analytical simulation programs for digital computers (requiring, in some cases, minor analog support) which must be generated by the computer itself by virtue of a compiler type automatic programming language. The existing languages are investigated and found unsuitable because of lack of suitable logic, protracted programming time or lack of usability by other than specially trained professional programmers. Some of the difficulties encountered are demonstrated by the construction of a working program for the prediction of system effectiveness for a simple system for which reliability and maintainability are considered. Suggestions for the structure of a suitable language are set forth.

Sponsor: Air Forcé, RADC

Contract: AF30(602)-2718

Contractor:

Status: Completed 1963

Report: RADC TDR 63-407 (available through DDC)

Computer: IBM 1620

Title: Effectiveness Simulation

Abstract: Computer program developed for analysis and
prediction of Reliability, Availability,
Maintainability and System Effectiveness for
an Airborne equipment with four independent
units.

Printed output indicates for every Kth flight
number of complaints, number verified, number
successfully repaired, start status probabilities
and individual unit characteristics.

Program is written to show general utility of
simulation program. T_'-' run of 500 flights
yielded no-complaint probability of 0.484 as
compared to 0.491 obtained analytically.

Note. Limited to Airborne system of 4 independent
units - effort needed to revise program to handle
variable number of units.

Sponsor: Air Force - WPAFB (AFSC-Dir.Strategic and Tactical)

Contract: AF 33(657)-10594

Contractor: ARINC Research Corporation

Status: Completed end of 1963 - thinking was input to
WSEIAC Study

Report: ARINC 267-01-7-419

SECTION V - COST EFFECTIVENESS

Title: Cost-Effectiveness Studies

Abstract: Cost-effectiveness studies for advanced
           Sea Based Deterrance

Sponsor: Navy, Special Projects Office

Contract:

Contractor: Stanford Research Institute

Status: Active

Reports: Vol. I and II "Weapons Systems Synthesis and
          Technical Evaluation for Advanced Sea Based
          Deterrance" (Classified Reports)

          Special Report I - Notebook of Cost
          Effectiveness Studies for Advanced Sea
          Based Detterance (Classified Report)

Computer: IBM-7090

Title: Evaluation Criteria for Associative
            Memories

Abstract: A method for evaluating the relative cost-
            effectiveness of a series of computer
            memories relative to performance per unit
            of total cost.

            Note: The underlying assumptions and approach
            are being held proprietary but the actual memory
            analyses and computations are included in the
            report of Phase I of the effort.

Sponsor: Air Force RAWID, Rome Air Development Center

Contract: AF 30(602)-3108

Contractor: Hollander Associates

Status: Completed

Reports: Phase I, Report 209-1 dated 28 December 1963

Title: Criteria for Systems Trade-Offs

Abstract: Phase I. Determine whether correlation exists
between both development cost and time, and the
ranges of system performance characteristics for
a given class of systems.

Phase II. If correlation exists, develop general
relationships equating the appropriate design
characteristics to over-all system development cost
and system development time.

Sponsor: Air Force, RADC

Contract: AF 30(602)-3702
AF 30(602)-3722

Contractor: Sylvania
ARINC

Status: Active

Reports:

Computer:

NOTE: The approaches to the problem are different in each case:

Sylvania

Approach - Actual system design, development time and cost
information, will be studied and retraced in detail for
several systems, each representative of a type in wide usage,
to realize the objectives above (Case history approach). In
addition computer simulation procedures will be utilized to
determine design vs cost parameters for hypothetical systems
of a given type.

ARINC

Approach - Actual system design, development time and cost data
will be collected from a large group of systems. Pertinent
information will be extracted, analyzed, correlated and sup-
plemented by engineering theory to realize the goals of the
objective.

Title: Economics of Ownership

Abstract: The economics of ownership program is designed to
           study system optimization with respect to cost and
           reliability. This program simulates the operation
           of weapon systems as a function of reliability and
           maintenance capability and, in turn, computes the
           availability. The effectiveness of any system is a
           function not only of its tactical capability, but also
           of its operational reliability and availability.
           Trade-off studies are made between initial cost and
           total maintenance cost. In addition, optimum spares
           investment and allocation can be determined along
           with maintenance personnel and facility requirements.

Sponsor: Autonetics Division of NAA (In-house)

Contract:

Contractor:

Status: Program currently being used.

Reports: No reports available

Computer: IBM-7094

Title: Cost and Availability Program

Abstract: A program developed and employed under a Navy contract
            provides reliability, maintainability, and availability
            indices at various levels of hardware complexity. Coupled
            with these, it provides several costs associated with the
            system's operation and support.

            The program accepts as inputs such observed characteristics
            as system operating time; number of failures at system,
            equipment and part levels; maintenance times; technician
            rating; echelon(s) at which repairs are made; replacement
            part costs; system and initial spares costs; and system
            life and utilization rate.

            The program provides as outputs:

                Reliability, maintainability, and availability
                indices at various hardware complexity levels.

                Costs, per operate hour, of

                        (1)   Initial procurement

                        (2)   Operation

                        (3)   Maintenance (labor and parts)

                Costs, per maintenance action, of

                        (1)   Labor

                        (2)   Parts

            The program has recently been adapted to accept data
            provided by an existing military activity (NATSF).

            Additional effort in improvement of this program could be
            devoted to inclusion of broader support costs, such as
            buildings, major facilities, costs of personnel above
            squadron level.

Sponsor: Navy - Bureau Weapons

Contract: N123(61756) 32994A(PMR)

Contractor: ARINC Research Corp.

Status: Completed

Reports: ARINC Report 285-01-4-467 (Confidential)

Computer: IBM - 1401

SECTION VI - SYSTEMS EVALUATION

Title: G.P.S.S. (General Purpose System Simulator)

Abstract: G.P.S.S. is a technique that provides a means of
            evaluating a proposed system. The systems'
            characteristics and behavior are modeled by a
            computer program which reacts to various
            operating conditions in a similar manner as
            the proposed system would react.

            Results are used to establish feasibility, compare
            alternatives and to gain insight as to the effect
            on system performance of a change in equipment
            parameters.

Sponsor: IBM (In-House)

Contract:

Contractor:

Status: Operating

Reports: Available from IBM

Computer: 7090 Series/Fortran   32K Memory
            7040   "   "   32K Memory (GPSS III only)

Title: GOSSIP (General Operating Systems Simulation Program)

Abstract: GOSSIP is a general program for simulating a number of states and activities with the operation of a complex system over a specified mission interval. It will simulate operating time in both normal and degraded modes, unit and system failures, corrective repair and influences of all of these on supply support effectiveness.

The program can handle very large networks (i.e., complete POLARIS Submarine). The outputs possible are (1) complex system reliability as a function of unit reliability, (2) availability and readiness analysis at given performance levels.

Used basically as a design tool for determination of logistics requirements.

Sponsor: Navy Special Projects Office

Contract:

Contractor: General Electric Tempo

Status: Active

Reports: Available

Computer: IBM-7090/Fortran and Kab

Title: Weapons Simulation

Abstract: Program to evaluate performance as a
           function of varying inputs.

           Long range program, will not complete
           most models until sometime after 1970.

Sponsor: BuWeapons

Contract:

Contractor: NOTS(P)

Status: Active

Reports: Status Report due April 1965

Computer: AN/USQ-20B(Digital); EA(Analog)

Title: Sonar Simulation

Abstract: Complete programming of direct path, bottom
           bounce and convergence zone sonar modes of
           operation. The model considers environmental
           and other sub-system inputs. It can be
           used for surface or submarine sonars.

Sponsor: Navy, Naval Electronics Lab/BuShips

Contract:

Contractor: NEL, In-House

Status: Active, ready for excercising 1 July 1965

Reports: NEL Report September 1964 on bottom bounce
           simulation; March 1965 for convergence zone
           and direct path operation.

Computer: AN/USQ-20A/MELIAC(International Algo(58)
           Compiler)

Title: Simple Digital Device Simulator

Abstract: Simulate the operation of digital computers.
Output is the state of all storage elements.

Sponsor: Air Force, AFSC

Contract:

Contractor: AMF

Status: Completed

Reports: "A Simple Digital Device Simulator", Rubin
and Hickey, AMF Company

Computer: IBM 7090/1

SECTION VII - CIRCUIT ANALYSIS

Title: E.C.A.P. (Electronic Circuit Analysis Program)

Abstract: Analysis to determine effect of environment,
            aging and production tolerances of parameters
            on circuit performance. User oriented program
            capable of yielding a thorough D.C., A.C. or
            transient circuit analyses.

Sponsor: IBM (In-House)

Contract:

Contractor:

Status: Program available and being used. Program being
          modified for IBM-7090/4.

Reports: IBM-1620 Electronic Circuit Analysis Program

Computer: IBM-1620, 40K Memory
            Fortran II

Title: NET-1

Abstract: Circuit Design model to evaluate circuit
performance for design optimization from
past performance electrical inputs. A
utility routine, it accepts system -
descriptions and part - specifications as
inputs and produces system behavior as out-
puts. Iterating voltages and currents at all
modes of operation are available as output
for both transient and steady state.

Sponsor: Los Alamos Scientific Laboratory

Contract:

Contractor: Sandia Corporation

Status: Active

Reports: NER-1 Analysis Program - Doc LA-2853 Los Alamos
Scientific Laboratory

Title: Statistical Circuit Analysis

Abstract: Programs provide a method of determining the statis-
            tical distribution of a circuit's output variables.
            Circuit output variables include voltages, currents,
            powers, gains, etc. The output variables determine
            the distribution of a circuit's DC operating points
            and frequency response. Most of the programs use a
            Monte Carlo method which simulates the random con-
            struction of a circuit from parts described by their
            distributions. The distribution of the output
            variables is determined by analyzing a large number
            of these circuits. The moment method program is an
            analytical technique which uses the propagation of
            variance formula to predict the mean and standard
            deviation of a circuit's output variables. These
            programs have been used to determine the probability
            of a circuit failing due to the components tolerance
            buildup.

Sponsor:

Contract: Company and Contract Funds

Contractor: Autonetics Division of NAA

Status: Programs currently being used

Reports: Autonetics Report "Reliability Analysis of Electronic
           Circuits" being reproduced by Defense Documentation
           Center.

Computer: IBM-7094 for several programs
            Autonetics RECOMP II for one program

Title: Parameter Variation Circuit Analysis Techniques

-ract: Parameter variation programs that vary the parameters
of a circuit in some predetermined manner to provide
the engineer with useful design data. Worst case
analysis programs provide absolute maximum and minimum
values of circuit's outputs. These worst case programs
were particularly useful in determining the power ratings
of resistors and transistors, voltage rating of capaci-
tors and other component stress ratings.

Some of the variational programs are used to determine
the effects on circuit performance when one or more
parameters is varied through a range of values. For
examples these programs have been used to determine
the frequency response of a circuit for several
different values of a component. This type of program
helps the engineers to design more reliable circuits.

Sponsor:

Contract: Company and Contract Funds

Contractor: Autonetics Division of NAA

Status: Program currently being used

Reports: Reports available from Autonetics

Computer: IBM-7094
Autonetics RECOMP II

Title: Transient Analysis

Abstract: Transient circuit analysis programs are used to
study the behavior of circuits as a function of
time. Of primary concern are the peak part
stresses that are associated with transients and
the over-all time response.

Several programs are available to supply this
information to design engineers. The "DEE"
(Differential Equation Evaluator) program gives
the time response for a set of simultaneous
equations written in terms of the LaPlace trans-
forms. SCAN transient analysis programs solve
simultaneous differential equations by the finite
difference method. This program has the added
capability of being able to handle non-linear
components. The "TRUMP" (Transient Response Using
Matrizant Procedures) finds the transient response
of linear and non-linear circuits using matrizant
procedures to solve the simultaneous differential
equations.

Sponsor:

Contract: Company and Contract Funds

Contractor: Autonetics Division of NAA

Status: Programs currently being used

Reports: Reports available on some programs from Autonetics

Computer: IBM-7094

Title: Radiation Analysis

Abstract: The "TRAC" (Transient Radiation Analysis by Computer) program analyzes the effects of nuclear radiation on semiconductor circuits. In its present form, TRAC is oriented toward the specific area of pulsed ionizing radiation, but is capable of including permanent damage/displacement/effects and E-M pulse effects. This program can simulate a radiation profile of a nuclear device more realistically than can be duplicated in a laboratory. The TRAC program is basically an advanced transient circuit analysis program with the additional capability of including radiation effects.

Sponsor: Autonetics Div. of NAA

Contract:

Contractor:

Status: Program currently being used

Reports: A paper available from Autonetics

Computer: IBM-7094

Title: Failure Mode Analysis

Abstract: Failure mode circuit analysis programs simulate
catastrophic part failures to analyze the fail-
safe characteristics of circuits. They are also
used to determine if associated parts will be over-
stressed and fail. They provide information which
can be used in defining test point allocation, and
in preparing fault isolation and repair procedures.
"SYCATE" was developed as an aid in the preparation
of maintenance manuals. The "AMAP" failure mode
analysis program is designed to fail all components
of a DC circuit to determine their effects on circuit
performance. The "ACFM" program is used to study the
primary and secondary failure modes of AC circuits.

Sponsor:

Contract: Company and Contract Funds

Contractor: Autonetics Div. of NAA

Status: Programs currently being used

Reports: Autonetics report in preparation

Computer: IBM-7094

Title: Logic Circuit Evaluation

Abstract: Analysis of cost-effectiveness of high-speed
computer circuits,

Note: The underlying assumptions and
approach are being held prepietary but the
actual analysis and computations will be
included in the report.

Sponsor: Army

Contract: DA(18)-119(SC)2461

Contractor: Hollander Associates

Status: Under way

Reports:

Title: Statistical Data Analysis

Abstract: The "ECAP" (Electronic Component Analysis Project)
computer program is an integrated system of analysis
programs used to analyze electronic part parameter
data. The statistical methods, techniques, and computer
programs are applicable to the majority of engineering
test data. This program was developed to analyze the
extensive reliability life test data generated in the
Minuteman Reliability Improvement Program.

The program had the following objectives:

(1) Improve reliability by obtaining failure mode
data and feedback for design and process
improvement.

(2) Completely characterize reliability of electronic
parts.

In addition to this integrated program, there are
numerous statistical computer programs written for
particular problems. These programs perform regression
analyses, develop pictorial computer output, and
perform such statistical operations as determining
the chi-squared function and Weibull distributions.

Sponsor: Air Force

Contract: Minuteman Project

Contractor: Autonetics Div. of NAA

Status: Programs currently being used

Reports: Minuteman Contract Report available through Air Force

Computer: IBM-7094

Title: A.C. and D.C. Circuit Analysis Program

Abstract: This program enables an analyst familiar only with basic techniques for circuit analysis to obtain a complete analysis of a circuit. The analysis options are (1) one-at-a-time parameter variation and sensitivity test to determine the effect of the input parameter change on circuit performance; (2) worst-case solutions with all components at their drift limits; (3) Monte Carlo analysis to determine what the large volume production spread of circuit performance might be; and (4) special solutions with specified combinations of limits on components. The method has been labeled a cookbook approach.

The program can be used either as a design tool for optimizing circuit performance or for determining the reliability of given circuits.

Note: Two major areas in which further development is needed are (1) incorporation of capability for transient analysis, and (2) eliminate the need for the analyst to write the loop equations (which can be a major source of error) and incorporate these into the computer program for equivalent circuits.

Sponsor: Navy - NOTS, China Lake, Calif.

Contract: N123(60530)-51224A

Contractor: ARINC Research Corporation

Status: Complete with efforts planned for computer generation of equations and to cover transient analysis.

Reports: (a) Proceedings of 11th National Symposium Reliability and Quality Control, Pages 12-21
            (b) Service to NOTS and no formal contract reports

Computer: 7090/94 Fortran II

Title: Master Parameter Variation Program

Abstract: Designed to perform statistical analyses of
electronic circuits, particularly digital
logic circuits. Program is capable of performing
virtually all engineering and statistical analysis.
Elements modeled are circuit parameter variation
analysis and reliability. Output is in form of
plotted histograms, various numeric values for
currents, voltages, relative sensitivity, etc.
Features of the program are: Monte Carlo parameter
variation, multiple parameter distributions
(maximum of 22 different distributions); high
efficiency, handles switches and circuits. Major
difficulty is in programming specific circuit
for analysis.

Sponsor: AFSC - Mfg Tech Laboratory - Research & Technology Div.

Contract: AF (33)657-8785

Contractor: ARINC Research Corporation

Status: Complete

Reports: ARINC Report 234-02-10-466 "Final Report on
Investigation of Factors Affecting Early
Exploitation of Integrated Solid Circuitry"
December 1964.

Computer: IBM-7090 or 7094/Fortran IV

Title: Application of Von Neumann Redundancy Techniques to the Reliable
Design of Digital Computers

Abstract: The study described herein consists of two parts: (1) a critical
analysis of the engineering problems that arise in the attempt to
implement various redundant information-processing concepts, and
(2) a detailed development, design analysis, and reliability
analysis of the application of functional majority logic to the
redesign of an ADDER used in a space guidance computer.

The analysis of the engineering problems arising in the implementation
of various information-processing redundancy concepts includes an
evaluation of all such applicable concepts developed to date, and
the implementation problems associated with each. Applicability of
these concepts to the mechanization of all the logic and control
functions normally required in a digital computer is investigated,
and a qualitative evaluation of the practical potential of the
various methods is presented herein.

One such concept, functional majority logic redundancy (FMLR),
is the subject of application and analysis in the design of a real
computer element, an ADDER used in an aerospace guidance computer.
Basic functionally-redundant AND-NOT and OR-NOT modules are developed,
and the ADDER logic is redesigned to make the most efficient use of the
module. An analysis of the comparative physical characteristics of the
redundant and non-redundant ADDER is provided for evaluating the space/
weight/ power trade-offs required in the effort to achieve increased
reliability in digital systems. The redundant design is the subject
of a detailed reliability analysis, which attempts to keep at a
minimum the simplifying assumptions which often dilute the applicability
of theoretical or conceptual studies to the design of real hardware.

It became apparent in the course of the study that the value of the
redundant design was affected as much by the mode as by the frequency
of part failure. Statistically valid information of a general nature
on part failure modes does not exist. In the absence of such in-
formation, ARINC Research has developed a mathematical reliability
model which defines the sensitivity of the design concept to the
failure modes of its constituent parts. This approach has a twofold
value: (1) when statistically valid data on part failure modes be-
come available, the value of the functional redundancy design concept
can be assessed from the families of reliability curves provided in
this report; and (2) the model demonstrates the value of developing
piece-part fabrication processes which will control failure modes.

SECTION VIII - FAILURE MODE AND EFFECTS ANALYSIS

Title: Mathematical Automated Reliability and
          Safety Evaluation (MARSEP) Program

Abstract: A computerized failure mode and effects analysis
            program. The program accepts as input (a) the
            description of the system composed of various
            electrically or mechanically connected components,
            and (b) a definition of system success. The
            computer then determines which combinations of
            component events are required for system operation
            or system failure in all modes of operation.

            Methodology based on work done for Sandia Corp.

Comment: This program does not provide a means for
           quantitatively predicting Reliability or Safety.
           It results in a failure mode and failure effects
           analysis.

Sponsor: Mathematica, Princeton, New Jersey (In-House)

Contract:

Contractor:

Status: Unsolicited presentation

Title: Thermal Analysis

Abstract: Programs are available which can solve a wide variety of thermal problems. Most of these programs are used to treat a unique thermal analysis problem. The transient analysis of heat transfer through an ablative material is an example of one of these programs. Two thermal programs, written by Autonetics, were used in support of the Minuteman program. One simulates the thermodynamic behavior of multi-layer boards with attached integrated circuits. The other studies the temperature distribtuion within an integrated circuit to determine average and "Hot Spot" temperatures for reliability considerations.

Sponsor:

Contract: Company and Contract Funds

Contractor: North American Aviation (Autonetics and other Divisions)

Status: Programs currently being used

Reports: Autonetics In-House Thermal Design Analysis Manual (Not presently available for distribution)

Computer: IBM-7094

Title: Study of Failure Theory (Metal Film Resistors)

Abstract: Study of the principal mechanisms of failure in
            deposited metal film resistors (precipitation
            and oxidation). A mathematical model of re-
            sistor behavior, involving at this time oxidation
            and precipitation, has been investigated and
            programmed for IBM-7090 computer.

            Results to date show poor correlation with test
            data; this is attributed to effects and mechanisms
            not yet incorporated in the model, and data
            available for validation studies represent mean
            value data for hundreds of resistors. The study
            is being continued.

Sponsor: Air Force, RADC

Contract: AF 30(602)-3251

Contractor: IIT Research Institute

Status: Study continuing as follow-on to Phase I studies

Computer: IBM-7090